Flood and Water Quality Management through Targeted, Temporary Restoration of Landscape Functions: Paying Upland Farmers to Control Runoff

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ABSTRACT: Floods have caused billions of dollars in damage to populated areas associated with river systems in recent years. Runoff associated with floods has resulted in deterioration of downstream water quality. The threat of flooding may be known weeks if not months in advance. Such nonstructural means as temporary storage of runoff on agricultural lands in the upland areas of the watersheds during periods when flood risks are high, may provide ecological benefits through reduced sediment runoff, soil carbon loss, and loading of nutrients to surface waters, at the same time diminishing the threat of downstream flooding. Local or regional resource managers or insurance industry consortia could establish contracts with farmers to store runoff by the temporary plugging of ditches, drainage systems, and similar practices until the flood threat has passed. In return, farmers would be paid an amount covering the loss of potential net revenue and the opportunity cost from use of the land for the period of runoff storage. Highly detailed topographic maps would be used to estimate storage capacity on a farmer's fields and hydrographic data would be used to estimate the volume of water from a precipitation event that must be stored in order to avert downstream flooding. When meteorological data suggest that a flood is imminent or that an extreme precipitation event is likely, the contractual agreements would be initiated. Case studies in select watersheds in Iowa show how the policy might lessen the social and environmental cost of floods.

Keywords: Agricultural conservation, economic incentives, floods, nonstructural flood mitigation, nutrient runoff, upper basin storage, water quality

In the ten years ending in 1993, average annual flood damages in the United States have been estimated to exceed \$3 billion (Interagency Floodplain Management Task Force 1994). The Corps of Engineers estimated that the Midwest Flood of 1993 alone caused some \$16 billion in damages. Furthermore, the rate of annual damages caused by flooding is on the rise with flood damage costs in fiscal years 1995 and 1996 amounting to \$5.1 and \$6.1 billion, respectively (FEMA 1997). If global warming continues and extreme weather events occur more frequently, as predicted (whether or not as a consequence of anthropomorphic activities), the social cost of events associated with extreme precipitation can be expected to increase in lieu of mitigatory actions that reduce the impact of extreme weather events (Karl 1999; UMAC 1999; and Watson et al. 1996).

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In response to the 1993 Midwest Flood, the President established the Federal Interagency Floodplain Management Committee to make recommendations to the administration on changes in current policies, programs, and activities of the federal government that would reduce risk and achieve environmental enhancement in the floodplain and related watersheds.

One of the key strategic goals for effective floodplain management identified by the committee was the preservation and enhancement of the natural resources and functions of flood plains. As further noted by the committee, the federal government should ". . . where appropriate, restore and enhance bottom land and related upland habitat and flood storage" (Interagency Floodplain Management Task Force 1994, p 67). Committee members envisioned a future flood management strategy in which "[upland of the floodplain,] federal-state-tribal-local programs to improve the treatment of lands, control new runoff, and restore wetlands would reduce the flows during frequent floods and shave the peaks off larger events" (p 67). Absent from the report's review of the literature are studies of the costs and benefits of nonstructural means for flood abatement in the Upper Mississippi. Also absent was a discussion of policies for implementing a program to manage runoff from upland areas.

Drainage has greatly reduced the water storage capacity of large amounts of cropland. Over 60% of the depressions in the closed drainage areas of Iowa, Minnesota, and Illinois are tiled or open ditch drained (USDA 1982). Subsurface tile drainage systems lower the water table and remove water from depressional areas. Open ditch drains constructed to act as outlets for removal of excess water serve as direct conduits to streams and eliminate a high percentage of the surface storage of the depressional areas (Person 1935). In Iowa, over 95% of the wetlands have been lost, nearly all losses occurring between the 1780s and the mid 1980s (Virginia Carter 1997).

Extensive wetland restoration or large scale construction in prime agricultural areas can be very expensive. There is, of course, the cost of the purchase of the land or the easement to the land and the establishment of the necessary hydrologic conditions. Each restored or constructed hectare of wetland in Iowa, for example, can easily cost \$9,876 and more (De Laney 1995; Alexander 1996). In addition, there are the costs associated with the loss of agricultural production, higher food prices, and the loss of revenue to local communities. It is this latter concern that has led the United States Department of Agriculture (USDA) to limit by policy the percentage of cropland (no more than 10%) that can be retired in any one county through the Conservation or Wetland Reserve Programs.

The higher peak flows resulting from the conversion of wetlands and other changes to the landscape also contribute to such water quality problems as increased loading of such nutrients as nitrogen and phosphorous from fertilizers applied to cropland (C. Hunt 1997). The average annual concentration of nitrate in the Lower Mississippi, for example, has increased two-fold since the 1950s (Turner and Rabalais 1991) and has contributed to the degradation of water quality for recreation, aquatic wildlife habitat, and drinking water (Orie Loucks 1995). Over 31% of the nitrogen flux to the Gulf of Mexico originates from the Upper Mississippi (USDA 1996). In addition, major rainfall events, particularly in late winter, cause most of the loading of phosphorous and sediment to surface waters (Goolsby 1993; The National Research Council (NRC) 1993). The excess nutrients transported through the Mississippi contributes to the hypoxic zone in the Gulf of Mexico, an area of over 6000 mi^2 (roughly 15,000 mi^2)near where the Mississippi and Atchafalaya Rivers flow into the Gulf, where there is not enough oxygen in the water to support normal fish populations.

Donald L. Hey and Nancy Philippi (Hey and Philippi 1997) have argued that land can be managed to provide the functions, such as temporary water retention and filtration, once naturally provided by wetlands. "We should be able to find sufficient land to create nodes within our drainage system where excess runoff can be stored and used for other purposes." They also suggest that ". . . the key to successfully implementing these solutions is in the strategic placement and scale of wetland restoration by reference to needs for flood damage reduction . . . By low scale engineering techniques . . . the flood storage capability of these soils can be greatly expanded" (p 68).

An alternative and complementary approach that can be pursued in conjunction with a long term policy of strategic wetland restoration is a voluntary program of temporary water storage on agricultural lands. For example, in the watershed of the Upper Mississippi, upland areas, particularly those areas that historically contained large amounts of wetlands, could potentially store significant amounts of runoff. During periods of high precipitation or in the late winter or early spring, the water storage function (surface impoundment and soil saturation) of converted wetlands can be temporarily restored by plugging drainage ditches and tile drains for the period of the events.

In select areas studied by investigators in the closed flow systems within the northern prairie portion of the Upper Mississippi River Basin (Wiche 1990), up to roughly 386,000 m^3 (809.6 ac ft^{-1} mi^2) of water per square kilometer could potentially be stored (i.e., water covering an acre of land at a depth of 15.2 in). Temporary water holding areas can be achieved through the use of simple structures like berms to hold back water or tile drain control devices to manage subsurface drainage and potential aboveground water storage (Don Pitts 1999). Flashboard risers at the lower end of fields, for example, have been shown to retain water on the fields during the spring or winter, keeping nutrients from running off the fields to adjacent waters and protecting water quality (USDA 1996). After the threat of flooding has abated, the temporary structures or plugs can be removed, releasing the water and restoring potential water storage capacity.

We use hydrograph data and data on flood storage volumes generated by the U. S. Geological Survey in Iowa City (Buchmiller 1998) to examine the feasibility of a policy that pays farmers to store water on their land during periods of extreme flood risk. Feasibility of the policy is defined not only in terms of the storage capacity of depressional areas that can, with relatively simple manipulations, be made to store water, but also the expected benefits of contracting with farmers to allow their upper basin land to be temporarily flooded relative to what otherwise would be lost to damage caused by floods. We assume that farmers would be willing to use their land for water storage if they could be assured of roughly the same profit from the land as they could expect from its use in crop production.

How do the expected benefits of averting flood damages, taking into account the costs and uncertainties of a nonstructural means to flood prevention, compare to the status quo? The agricultural land that we considered includes depressional areas that may have once been wetlands but also non wetland crop and pasture land that can be made temporarily to store water through the use of simple structures.

Study Area, Methods, and Analysis

The method for hydrographic analysis of floodwater discharge and volume, and the Geographic Information System (GIS) analysis (U.S. Department of the Interior 2000)of potential storage volume and hectares of land potentially available for water storage are described in Buchmiller et al. (1998). Flood storage is defined as the potential storage capacity of upland depressional and other areas that with lowscale engineering techniques could be made to store water and hence to reduce the peak flow runoff associated with flooding events.

We derive our estimates of flood storage costs using estimates of hectares of land that would be necessary to store the flood discharge volumes. These estimates, though plausible because they are based upon past discharge events, must not be construed as the absolute minimum necessary land area to prevent actual flood events of various magnitudes that may occur. Because the intent of this paper was to explore the feasibility of a policy option, not to explore its implementional requirements, we used conservative assumptions regarding costs and benefits which, as indicated in the tables, tended to overestimate number of acres, and hence, the dollar cost. Finally, we estimate benefits from federal and local flood damage estimates and from actual outlays to farmers that were made under federally insured crop insurance and agricultural crop damage assistance.

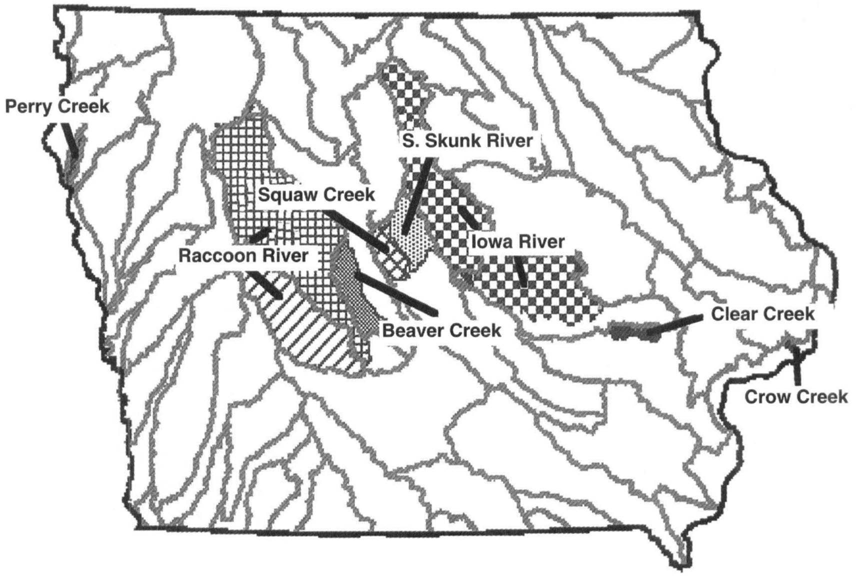

Figure 1: Iowa study areas (shown in patterns) in relation to 8-digit hydrologic units.

Table 1. Locations, dates, and volumes of selected floods in Iowa.

Gaging Station	8-Digit HUC	Drainage Area (hectares)	Flood Events	Flood Water Volume (in cubic meters, exceeding indicated RI)					
				10	25	50	100	200	500
Crow Creek at Bettendorf	part of 07080101	4,610	Bettendorf, 6/16/90	662,121	197,280	18,865	0	0	0
Iowa River at Marengo	07080207 part of 07080208	723,668	several communities on the Iowa R., 7/19/93	125,766,000	37,359,900	10,159,920	59,924	0	0
Clear Creek near Coralville	part of area 07080209	25,409	Coralville, 6/16/90	6,054,030	2,453,670	648,558	0	0	0
			& 7/6/93	2,268,720	0	0	0	0	0
S. Skunk R. near Ames	part of 07080105	81,558	Ames, 7/9/93	11,146,320	4,833,360	2,256,390	604,170	0	0
			& 8/16/93	8,877,600	3,809,970	1,590,570	305,784	0	0
Squaw Creek at Ames	part of 07080105	52,409	Ames, 6/17/90	2,355,030	691,713	15,289	0	0	0
			& 7/9/93	19,604,700	10,529,820	6,904,800	4,377,150	2,133,090	358,803
Beaver Creek near Grimes	part of 07100004	92,725	Johnston, 7/10/93	18,741,600	10,048,950	5,215,590	1,972,800	224,406	0
Raccoon River at Van Meter	07100007 most of 07100006	891,247	W. Des Moines & Des Moines, 7/10/93	125,766,000	69,417,900	38,099,700	16,892,100	4,216,860	0
Perry Creek at 38th St., Sioux City	most of 10230001	16,861	Sioux City, 5/19/90	817,479	151,659	0	0	0	0

Most of the watersheds chosen for this study—the exceptions are Perry, Clear, and Crow Creeks—fall within the Des Moines Lobe, the most recently glaciated region that once contained a very high incidence of depressional, palustrine wetlands (Figure 1). Table 1 lists the gaging station, the eight digit Hydrologic Unit Code (HUC) for the basins, the size of the drainage area upstream of the gaging station, recent flood events, and flood volumes exceeding various recurrence intervals (RI). HUC information was included because most economic data are only available by HUC. Figure 1 also shows the locations of the watersheds and their relation to the HUC. Figure 1 reveals that some of the HUC areas were larger than the drainage basin and that some of the larger basins contained more than one HUC area. The lack of congruity between the study area and HUC may create some bias when data from HUCs are used to draw inferences to study area watersheds. This problem was addressed by using the most conservative assumption that would produce either higher cost estimates or lower estimates of benefits. The runoff had to have originated from within the watershed and hence could be reduced by means of landscape management practices. Furthermore, the floodwater runoff must not be affected by dams or diversions.

The eight stations provided estimates of the volumes of water that were discharged during recent flood events in the respective watersheds and the likelihood that flood events of similar magnitude would occur, or the RI. The probabilities are based on statistical analyses of 10 years or more of historical records at each gaging station.

For Crow Creek, which constitutes part of the much larger watershed, with eight digit USGS identification HUC 07080101, the gaging station is located at the bottom of a drainage area that covers 4,610 ha (11, 380 ac). On June 16, 1990, a runoff event occurred that caused flooding at Bettendorf, during which a peak discharge of 218.2 m3 (7,700 ft2) of water per second passed the gaging station. The likelihood that a flood event of such magnitude will recur is once every sixty years. The volumes of flood water from this particular flood event exceeded a 10, 25, and 50 year RI at 662,121, 197,280, and 18,865 m3 (537, 160, and 15.3 ac ft-1), respectively. Depending on the level of flood protection available to the town, the above amounts provide a very rough estimate of the volumes of water that would have had to be stored upstream of the gaging station to have reduce flood peaks and therefore flood damage for this particular event.

Since the volumes in excess of an RI can vary—sometimes greatly—we cannot generalize from these volumes for RI exceeding all future flood events. The town of Coralville was flooded twice in the past seven to ten years, once on June 16, 1990 and the second time on July 6, 1993 with flood discharges of 289 m3 (10,200 ft3) per second with a recurrence interval of 90 years and 191.6 m3 (6,760 ft3) with a recurrence value of 25 years, respectively. The total volume of water that would have had to be stored to have prevented a flood with a 90 year RI is 6,054,030 m3 (4,910 ac ft-1), assuming that there was protection for at least a 10 year frequency event. For a flood that has a 25 year RI, the volume would be 2,453,670 m3 (1,840 ac ft-1) . To do so requires an historical analysis of how large the variability is with regard to flood RIs and floodwater discharges. Nevertheless, it does give us a rough and reasonably robust estimate of peak discharge volumes between RIs that can be used for assessing the feasibility, in general, of mitigation options.

Notice that the volumes in the example floods are volumes in excess of the RI at the gage. In order to prevent a flood in excess of the RI, that amount of water needs to be prevented from reaching the gage site at exactly that time, which is not a trivial feat. This has usually been accomplished by designing diversion channels or large dams for flood control. In our example, in lieu of natural or temporary structures to direct flow, excess capacity in terms of land would have to be contracted for in advance of an anticipated high discharge event to account for the uncertainties regarding time and flow.

The Geographic Information System (GIS) procedure that was developed to identify hypothetical potential flood storage areas classified each cell within each watershed into four slope criteria according to differences in elevation among its eight neighboring cells: less than 2.%, 5.%, 7.%, and less than 10.%. Polygonal areas of less than 4 ha (10 ac) were arbitrarily removed from the analysis on the assumption that these were too small to be considered as part of a comprehensive flood management strategy. Furthermore, polygonal areas that intersected streams identified as second order or greater were removed from the analysis based on the assumption that these areas were not upland areas but were floodplain areas that might be inundated during a flood event. The remaining polygonal areas within each watershed were then summed according to slope criteria.

The estimates of the number of hectares that could potentially store water during flood events are presented in Table 2. We present the estimates only for the first three landslope criteria because the fourth was not needed for flood storage for the purposes of this study. For example, Crow Creek, which has a drainage area upstream of the gaging station of 4,610 ha (11,387 ac) has 911 ha (2,250 ac) contained within depressional areas of slopes of less than 2.5%, or 20% of the watershed area, 1,692 ha (4,180 ac) with slopes of less than 5% which amounts to 36.7% of the total land area, and 2,343 ha (5, 790 ac) with slopes less than 7.5% or 50.8% of the watershed. The amount of low relief land surface within any particular watershed is directly related to the physiography of the watershed. Areas of Iowa that were most recently glaciated have the highest percentage of low relief land areas.

The potential flood storage volumes were then estimated by multiplying the various landslope category areas within a watershed by the following hypothetical uniform inundation depth: 0.30 m, 0.61 m, or 0.91 m (1 ft, 2 ft, and 3 ft). These preliminary volumes were then divided by 2 to conservatively account for depth variability presumed within each polygonal area, prior standing water, vegetation, or myriad other reasons. For instance, at Crow Creek, the potential storage volumes ranged from 1,380,960 m^3 (1,120 ac ft^{-1}) at the 2.5% slope criterion and 0.3 m (1 ft) depth to 10,543,500 m^3 (8,551 ac ft^{-1}) at the 7.5% landslope criterion and 0.91 m (3 ft) depth. In other words, 2 m^2 of land area are needed to store 1 m^3 of water.

We presume that the lower the low relief criterion and the lower the flood depth necessary to prevent a flood event, the more plausible is the scenario that the estimated volume of water can actually be stored during the period of runoff discharge. Basins of greater slopes are more likely to encompass structures, such as roads or buildings. Furthermore, greater flood depths may require more action on the part of the landowner, such as the construction of berms across ditches rather than just the temporary plugging of tile drains, to achieve these depths. The number of separate sites on which to store water is also likely to affect the feasibility of a policy of temporary storage of water on upland agricultural lands. The more sites, the more drains and tiles that require action to prevent the discharge of water before or during a precipitation event.

Temporary storage of water can be achieved through the use of simple structures, such as subsurface control drainage structures (Zucker 1998), flashboard risers to block drainage ditches (USDA 1999), furrow diking (Sanabria 1999), flow restricted culverts under roads that separate or transect fields and berms, and field borders to retain or restrict the flow of runoff and flood waters (North Carolina State University 1997). Some small homemade structures [with a weir less than 0.61 m (24 in) wide] may cost less than $300. A large prefabricated structure [with a weir more than 1.83 m (6 ft) wide] may have an installed cost of more than $3,000 (North Carolina State University 1997). For example, for a 40.49 ha (100 ac) field with a rise of 0.76 m (2.5 ft), or three structures, would be required at an initial cost of $1,650 per structure or a total cost of $4,950. Assuming an expected life of at least 20 years, the annual amortized cost, with an interest rate of 12% and hence an amortization factor of 0.13388, would be $662.71 ($4,950 x 0.13388) or $16.35 ha ($6.62 ac).[1]

For a USDA National Resources Conservation Service (NRCS) water control project in the Upper Chester Watershed of Delaware, the average cost per acre of water control structures for four locations with a total drainage area of 266.8 ha (659 ac) amounted to $37.70 (Kemmerle 1999). Using the same amortization factor, the amortized cost is roughly $12.35 ha ($5 ac). The operating cost is quite small and is difficult to separate out from normal production costs of producing crops. The one time cost of preparing field borders, assuming that 2% of the total field area would be used at an average cost of $607.3 ha ($1,500 ac) that are actually treated, the cost would be approximately $74.10 ha ($30 ac) with an amortized cost of $9.88 ha ($4 ac).

For the purpose of simplifying this analysis, we assumed that the annual, amortized cost per hectare associated with

Table 2. Potential flood storage land area and volumes for drainage basins in Iowa.

Gaging Station	Drainage area upstream of gaging station (hectares)	Watershed hectares in specified landslope criteria			Estimates of total potential flood storage volume (m^3), for land slope criteria and inundation depths of 0.3, 0.61, and 0.91 meters		
		<2.5%	<5%	<7.5%	<2.5% x 0.3m	<5% x 0.61m	<7.5% x 0.91m
Crow Creek at Bettendorf	4,610	911	1,692	2,343	1,380,960	5,153,940	10,543,500
Iowa River at Marengo	723,668	87,415	181,710	250,509	133,164,000	553,617,000	1,127,290,500
Clear Creek near Coralville	25,409	1,105	2,517	3,719	1,676,880	7,669,260	16,735,500
S. Skunk R. near Ames	81,558	16,674	33,995	48,159	25,399,800	103,572,000	216,715,500
Squaw Creek at Ames	52,409	6,313	14,084	21,490	9,617,400	42,908,400	96,705,000
Beaver Creek near Grimes	92,725	14,650	31,890	46,135	22,317,300	97,160,400	207,607,500
Raccoon River at Van Meter	891,247	226,632	367,872	461,358	345,240,000	1,120,797,000	2,076,111,000
Perry Creek at 38th St., Sioux City	16,861	92	334	603	140,562	1,017,225	2,713,500

installation and maintenance of simple structures or practices to enable temporary water storage is $17.00. The actual amount is likely to be lower if one takes into account the direct benefits to farmers from controlled drainage and reduced surface runoff, and different, less conservative assumptions regarding the interest rate (lower) for amortizing the upfront costs.

We used the Conservation Reserve Program's (CRP) average annual rental rate for the respective counties, minus the value of the land if it were used for grazing, as the starting point for estimating the revenue lost from foregoing crop production. The CRP is a federal program that contracts with farmers to retire crop land for ten year periods in return for an annual payment. Highly erodible land, wetlands and their associated upland areas, and lands important for the protection of water quality are eligible for inclusion in the program. The CRP rental rate for the fifteenth (1997) sign-up serves as a good indicator of what farmers demand for temporarily retiring land that could otherwise produce an agricultural crop. Where a watershed extends across a number of counties, the average rental rate for all the counties is used. Acceptance of the land into CRP precludes most agricultural activities, including grazing, on land that is inconsistent with the natural resource benefits that the land is expected to provide. On the other hand, this proposed program of paying for temporary water storage would allow grazing and other alternative uses of the land. The average cash rental rate for use of lands for grazing for the period 1992 to 1996 in Iowa was $77.93 ha ($31.56 ac) (USDA 1997).

The assumption implied by our choice of the CRP rental rate as a conservative estimate of the opportunity cost of temporary use of cropland for water storage is that producers are profit-maximizers and risk-averse. If the rental rate is high enough, they prefer a guaranteed payment to an uncertain higher return for producing a crop. It is used as a good proxy high estimate of the cost of compensating farmers for temporarily using their lands for water storage, against which we compare the benefits of averted flood damages.

Under a program of contracting for temporary upper basin storage, costs would not accrue until owners of agricultural lands are alerted to take an action to retain water on their lands and a severe precipitation event occurs that results in the loss of revenue from the land. The opportunity cost to farmers can range from nothing—if the action resulted in a delay in planting that did not result in a yield or expected revenue loss from the crops produced on that land—to a total loss of the crop and hence no profit. In the latter case, the opportunity cost that the government would have to pay farmers to enlist their land into the program would include both the cost incurred in putting in a crop that was subsequently lost and the loss of expected profit from the crop.

The CRP payment covers only what farmers expect for foregone profit from not growing a crop. Since it does not include the cost of producing a crop, it does not necessarily represent a worst case estimate of outlay for using land for temporary runoff retention. We can fairly and reasonably assume, in the event of an extreme weather occurrence, that most land falling within our depressional areas would normally be eligible to receive federal assistance from the U.S. Department of Agriculture's Catastrophic Crop Insurance and Noninsured Crop Disaster Assistance Programs[2] agricultural assistance.

The programs provide an indemnity payment of 60% of the expected market price of the crops that would have been harvested from the land, which roughly represents the out-of-pocket expense to the producers of having put in the crop. If crop or disaster insurance coverage would continue under a contract for temporary runoff storage, then only the loss of potential profit for production of a crop on the affected land would have to be covered by the flood mitigation program.

Manipulation of drainage or runoff for water storage could, under current rules of the crop insurance program, disallow crop insurance payments. In this case, either the rules governing federal crop insurance indemnification and disaster assistance (just regarding to land covered by water storage contracts) would have to be changed or the contract agreement would also have to cover production costs when no other crop could be grown. Nevertheless, in either case where the land is or is not under a water storage contract, the cost to the federal government for crop insurance or disaster assistance, on the one hand, or incurred costs in planting under a contract for water storage, on the other, is likely to be similar.

Furthermore, the activation of the conditions of the contract for temporary upper basin water storage would, under most circumstances, not result in the total loss of crop production for the year. In many, if not most cases, temporary water storage would not preclude its subsequent use for agricultural production. The return on the land for agricultural production for that year would be expected to be less, though not likely zero, as under the payment conditions of CRP. If temporary runoff storage occurs during the spring, the delay in spring planting may simply mean the planting of soybeans rather than corn, a crop that requires a longer growing season. Alternatively, if water storage occurred after planting, the land may still allow for hay production or livestock grazing after seeding with a cover crop.

By entering into a contract for water storage in the event of extreme weather events, producers are, in effect, ensuring themselves against profit loss at little additional expense. The actual inducement for landowners to participate in the program, since it comes at little cost to them, need only be a fraction of the CRP rental rate. How much per unit of land short of the CRP rental rate depends largely upon: 1.) the landowners' perception of the cost of installing and maintaining the devices; 2.) the time and effort necessary for maintaining and operating the practices or devices for temporary upper basin storage; and 3.) what remaining profit farmers or landowners think they can make from draining the fields and producing a crop or agricultural commodity in what remains of the growing season. Since the intent of this study is to examine the feasibility of a policy option, not to make the best prediction of the cost of actual implementation of a program in a specific area, we use the more conservative values that are more likely to overestimate rather than underestimate actual costs.

Most communities are not built in a 10 year flood plain, and hence, do not need protection against floods of 10 year recurrence intervals. Nevertheless, some communities may need protection against a 25 year (or less frequent) flood event because the cost of removing structures to higher ground may be prohibitively expensive. Floods greater than 100 year events may represent an acceptable risk. Hence, the amount of land needed for storage and, consequently, the cost of the program depends upon the desired level of risk reduction. In this analysis, we assume that communities want enough risk reduction to prevent, at the lowest cost, flood events of a given likelihood (or RI) or, stated alternatively, to contain flood volumes that equate to or exceed the RI that corresponds to their most recent flood.

Table 3 indicates preliminary estimates of the floodwater volumes greater than the

Table 3. Flood storage costs.

Gaging Station	Floodwater volume in cubic meters greater than indicated RI	Estimated # of hectares needed for storage*	Percentage of water-shed acreage	Hectares potentially available at indicated lowest relief criterion	Rental rate per hectare†	Estimated cost
Crow Cr.	197,280 (25)	$ 259	5.6%	911 (2.5%)	$ 193	$ 49,919
Iowa R.	37,359,900 (25)	$ 49,086	6.8%	87,480 (2.5%)	$ 167	$ 8,173,309
Clear Cr.	2,453,670 (25)	$ 3,224	12.7%	3,722 (7.5%)	$ 157	$ 505,007
S. Skunk	2,256,390 (50)	$ 2,965	3.6%	16,686 (2.5%)	$ 190	$ 563,261
Squaw Cr.	6,904,800 (50)	$ 9,072	17.1%	14,094 (7.5%)	$ 188	$ 1,704,810
Beaver Cr.	5,215,590 (50)	$ 6,853	7.4%	14,661 (2.5%)	$ 160	$ 1,094,561
Raccoon R.	38,099,700 (50)	$ 50,058	5.6%	226,632 (2.5%)	$ 158	$ 7,933,692
Perry Cr.	151,659 (25)	$ 200	1.1%	334 (5%)	$ 134	$ 26,882

* Assumes an average depth of 0.15 m of water storage per hectare and a doubling of the number of hectares to address uncertainties of flow and timing.
† Assumes average CRP rental rates for the counties covered by the watershed.

indicated RI discharges that would have to be retained if discharge events similar to those in 1990 and 1993 were to occur in the future, as well as the amount of land to retain these volumes and estimates of the cost for the use of the land. If we assume that twice as much land is needed to store a given volume of water at a targeted depth of inundation because of prior standing water, vegetation, or myriad other reasons (i.e., 2 m^2 of land area are needed to store 1 m^3 of water), and we assume a doubling of this land area is necessary to compensate for uncertainties in flow and timing—a reasonable assumption that serves this discussion of policy, but one which would have to be tested in actual implementation of the program—we arrive at an estimate of the amount of land for upper basin water storage to achieve protection against all but flood events of 100 year and greater frequencies. These estimates of land areas vary from 1.1% of the watershed for Perry Creek to 17.1% for Squaw Creek upriver from Ames.

The cost associated with temporarily storing water on these lands (not including the cost of the control structures) would range from a low of $134.42 ha ($54.44 ac) in the Perry Creek watershed to $192.74 ha ($78.05 ac) for Crow Creek. The cost per extreme precipitation event would range as high as $8,173,728 to provide protection against flood events with an RI of 25 years or greater in a watershed of 723,668 ha (1,787,460 ac) such as in the Iowa River watershed, to $26,882 for a small watershed, such as the Perry Creek watershed with a drainage area of 16, 861 ha (41,646 ac).

The net benefit of a program of temporary upper basin is measured in terms of the value of averting flood damages minus the cost of achieving the greater level of protection. With perfect hindsight and, consequently, knowledge of the likelihood of an extreme weather event, the choices are clear, as shown by the data on damages in Table 4.

Presented for all floods are data on federal outlays (by county) for Federal Emergency Management Administration (FEMA) disaster assistance for clean up and reconstruction, federally subsidized

Table 4. Outlays for crop insurance, disaster payments, CRP and FEMA clean up, and infrastructure costs.

	Federal crop insurance outlay for counties covered*		Agricultural disaster payments*		CRP hectares in county(ies) 1997	Total annual CRP cost in county(ies)	FEMA approved flood clean up and infrastructure costs (by county)[1]			City-estimated costs (public and residential)
Gaging station	Flood year 1990	Flood year 1993	1990	1993			1990	1993	1990-1997	
Crow Creek Scott Co.	$381,611		--		41.3	$11,257	$2,024,244			$954,464 (Bettendorf)
Iowa River Iowa, Benton, Tama, Poweshiek, Hardin, Marshall, Grandy, Franklin, Wright, Hancock Co.		$36,288,412		$42,616,610	3,608.1	$847,657		$3,022,052	$3,349,886	
Clear Creek Johnson, Iowa Co.	$478,333 (Johnson)	$5,676,349	$413,015	$7,995,535	4724.3	$1,103,129	$507,370	$5,784,765	$ 6,638,222	
South Skunk Story, Hamilton Co.		$13,613,155		$11,692,717	132.8	$35,416		$10,446,973 (Hamilton, Story, Boone Co.)	$11,943,415 (Story, Boone, Hamilton Co.)	$10,482,880 (Ames, 1993)
Squaw Creek Boone, Story, Hamilton Co.	$1,176,937 (Story)	$10,183,073	$43,065	$8,506,000	349.1	$92,030	$335,049 (Boone)	$10,446,973 (Hamilton, Story, Boone Co.)	$11,943,415 (Story, Boone, Hamilton Co.)	$10,482,880 (Ames, 1993
Beaver Creek Polk, Dallas, Boone Co.		$4,753,088		$6,491,855	509.9	$123,470		$22,060,198	$24,522,714	
Raccoon River Sac, Dallas, Guthrie, Greene, Carroll, Calhoun, Webster, Pocahontas, Buena Vista Co.		$28,568,549		$25,129,549	2800.6	$626,756		$5,258,898	$6,331,157	$197,353,000 (Des Moines, 1993)
Perry Creek Plymouth, Woodbury Co.	$573,613 (Woodbury)		$355.542		2385.0	$509,572	$1,079,095		$3,412,916	

*Information is only available by county and therefore must be considered only a rough approximation of the disaster outlays by study area watershed.

catastrophic crop insurance, and non insured agricultural disaster assistance. Data on uninsured or private flood costs to residences and businesses were not available for all watersheds and flood events. For most counties for the 1990 and 1993 floods, the bulk of the damages occurred to agriculture. Because the data are presented by county, the monetary benefits of upper basin storage are only approximated for the watersheds studied. Furthermore, since some of the watersheds share counties, total estimated county costs associated with flood damages are accounted for more than once in these instances. We include data on CRP land and its costs for purposes of comparison with federal outlays for agricultural land retirement in the indicated counties.

If risk managers could perfectly predict weather events and estimate exactly (or at least within reasonable bounds) the amount of land needed to retain peak discharge, they need only compare the cost figures in Table 3 with the damage estimates in Table 4 to determine the benefit of contracting for upper basin storage. For the Crow Creek watershed, the $50,000 cost of temporary water storage to reduce the risk of flooding for a one in for 25 year runoff event represents merely a fraction of the nearly $3 million in flood damages, as occurred in 1990. The cost of nonstructural flood risk reduction for Ames, Iowa to protect against 50 year frequency flood events amounts to $563,200 for the South Skunk and roughly $1.7 million for Squaw Creek. The averted damages amount to at least $21 million.

Finally, an expenditure of roughly $8 million for temporary upper basin storage in the Raccoon River Watershed could possibly avert nearly $208 million in flood damages to Des Moines and its residential environs. In only one example, the Iowa River watershed, might contracting for water storage not make economic sense because the contracting cost would exceed $8 million, yet the benefits, in terms of flood damage averted, only amount to slightly more than $3 million. This ratio may change, however, with data on residential and unreimbursed private costs associated with historical flooding.

Unfortunately, risk managers must make decisions under uncertainty since neither can weather be predicted with sufficient accuracy to avert the issuing of false alarms to plug drainage ditches and store water, nor can the magnitude of precipitation events be precisely estimated. No program, whether structural or nonstructural, can be guaranteed to perform one hundred percent of the time. Even if the community adopts measures to avert a 100 year frequency flood, there is still the roughly 1/100 chance every year that a flood greater than a 100 year RI discharge event will occur. Furthermore, should predicted consequences of global warming actually occur, there would be an increase in the frequency of extreme weather events that can cause flooding (Watson 1995). Therefore, the benefits of risk reduction must be expressed in terms of probabilities. The choices that a risk manager makes under uncertainty are illustrated by the decision flow diagram in Figure 2.

If we assume that the community wishes to achieve protection against flood volumes that exceed the 25 year RI discharges (50 year RI are indicated for larger watersheds), then risk managers will activate the conditions of the contract and alert landowners to retain runoff on their lands whenever there is a high likelihood of an extreme precipitation event. Let us assume that they make the call for temporary upper basin storage whenever they believe there is a 50% likelihood of a precipitation event that, given the conditions of the landscape, could result in a volume of discharge that exceeds a 25 year (or 50 year) RI discharge.[3]

For events resulting in an exceedance of the 25 (or 50 year) RI discharge, we make the worst case (conservative) assumption that the entire agricultural crop is lost and farmers are compensated the full amount of what they would have earned in profit on the crop. For false alarms when predicted high peak discharge events do not materialize, there is still likely to be some damage to crop production by the temporary storage of runoff. Since it would not be necessary to hold the water on the land for an extended period under conditions of a false alarm, there would be less loss of yield than under a genuine threat. Farmers could, soon after the false alarm, unplug ditches and release the water from their fields.

Let the default assumption in this case be that the expected yield on the affected land area declines by only 1/4, that is, the per hectare payment would be triggered on only a quarter of the land (though this is an assumption that needs testing, for the purpose of this study it is conservative and likely to overestimate costs). Finally in all other years when floods are not anticipated, there is no cost, except for those associated with maintenance of the systems, since the contract conditions are not triggered.

Thus, at 50% accuracy (25% for small watersheds) in predicting peak discharges with a 25 year RI, there is 0.08 (0.16) probability in any year that a risk manager will call for water storage. Finally, whenever a precipitation event occurs that exceeds the 25 year (or 50 year) RI discharge, there is a 25% probability that it will exceed a 100 year RI.

The expected benefit of a contract program versus no program becomes

B_{exp} = ($prob_{flood}$ x D + $prob_{not\ flood}$ x 0) - {$prob_{plug}$[$prob_{correct}$((prob < $_{capacity}$ x C) + (prob > $_{ca-}$

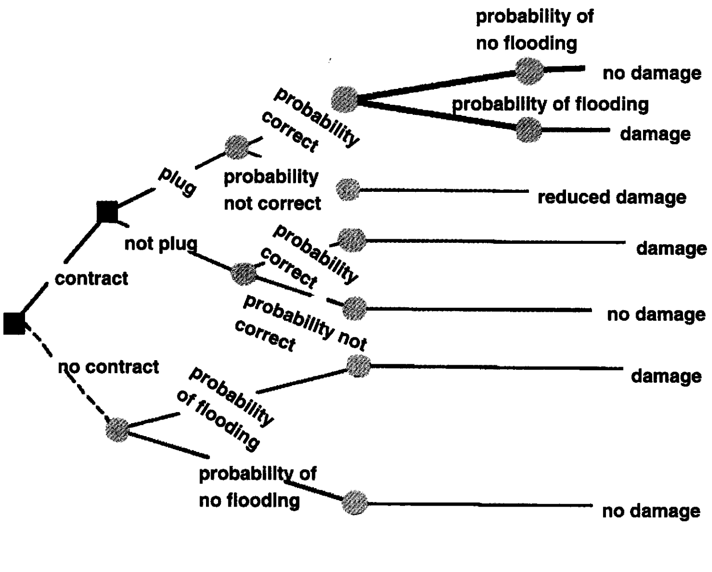

Figure 2. Decision flow diagram of expected benefits from Upper Basin storage.

$_{pacity} \times (C + D)) + 0.25\ prob_{incorrect}\ C] + prob_{not\ plug} \times 0\}$ (1)

where: probplug = the probability in any year that the risk manager will activate contract conditions to store runoff

$prob_{not\ plug}$ = the probability in any year that the risk manager will not activate contract conditions to store runoff

$prob_{correct}$ = the probability that a pre diction is correct

$prob_{flood}$ = the probability in any year that an extreme precipitation event will result in a peak discharge that exceeds the 25 year (or 50 year) RI

$prob_{not\ flood}$ = the probability in any year that an extreme precipitation event will not result in a peak discharge that exceeds the 25 year (or 50 year) RI

$prob_{>capacity}$ = the probability in any year that an extreme precipitation event will result in a peak discharge that exceeds the upper basin water storage capacity given contracts are activated

$prob_{<capacity}$ = the probability in any year that an extreme precipitation event will not result in a peak discharge that exceeds the upper basin water storage capacity given contracts are activated

D = downstream flood damage (not including damage to agricultural crops)

C = expected cost of a program of contracting for upper basin storage.

Results

In seven of the eight watersheds (Table 5), the expected benefits are positive given the assumptions described, suggesting that a risk manager, desiring to reduce public and private costs associated with floods, could save money by contracting for upper basin storage. Only in the Iowa River watershed would contracting not necessarily make strict economic sense unless we make assumptions regarding the magnitude of private or uninsured flood costs. By setting equation (1) to zero and solving for D, downstream flood damage, we find that contracting for upper basin storage becomes positive in the Iowa River watershed, if flood damages to be averted amount to at least $13.6 million. Deciding upon a lower level of risk reduction, such as protection against a precipitation event that can result in a 30 year RI peak discharge, serves to reduce the magnitude of D required to less than half of this amount and make temporary upper basin storage economic even for this watershed.

Table 5. Expected benefits of temporary upper basin storage.

Gaging station	Expected benefits
Crow Creek	$ 85,864
Iowa River	($ 318,025)
Clear Creek	$ 138,194
S. Skunk River	$ 195,219*
Squaw Creek	$ 166,677*
Beaver Creek	$ 193,238
Raccoon River	$ 1,827,772
Perry Creek	$ 30,498

* Overestimation of benefits is due to impossibility of breaking out separate flood disaster costs that are aggregated by county.

These results may underestimate the expected benefits of upper basin storage if a program of planned water retention on agricultural land also serves to reduce outlays for crop insurance and agricultural disaster assistance. The total volume of water in the watershed during an extreme precipitation event is likely to be retained on fewer hectares at greater depths rather than being spread out more thinly on a greater amount of land. Retaining runoff on upland agricultural lands also serves to reduce runoff and thus, reduce the likelihood of agricultural damage in the lower reaches of the watershed.

Without a detailed hydrological modeling analysis which is beyond the scope of this study, we cannot precisely estimate what the reduction in flood related agricultural damage would be from upper basin storage. Nevertheless, we do know that upper basin storage need only reduce agricultural costs by a small percentage to have a large impact on expected benefits. In the Iowa River watershed, for example, a 10% reduction in agricultural damage, or $8 million, would cause expected benefits to become positive since reductions in expenditures for agricultural damages on noncontract hectares would accrue whenever upper basin storage on contract land was triggered.

Discussion

The results of the analysis of eight watersheds in Iowa suggest that a program of storing runoff in upper basin depressional areas to lessen the risk of floods, under a variety of reasonable circumstances, lead to tangible savings to social welfare by preventing downstream flood damages to communities. In addition, the reduction in peak runoff rates leads to reduced sediment loss and decreased loading of such nutrients as phosphorus and nitrogen to surface water, which could result in improved surface water quality (Zucker 1998; Person 1936; National Research Council 1993). Inclusion of intangible and other tangible benefits, such as those that would accrue to wildlife habitat or drinking or surface water quality, would tip the scales even further.

Upper basin storage complements a program of targeted land retirement that together have as a goal the prevention of floods and protection of water quality. The first part, as has been suggested by others (e.g., Hey and Phillippi; Constance Hunt; De Laney), involves the strategic targeting of the Wetland Reserve or Conservation Reserve Programs toward lands that can be restored to wetlands and that can intercept intermittent late winter or spring runoff. Retiring the amount of land sufficient to retain the volume of water corresponding to the average discharge from late winter or spring precipitation events would create a buffer between intensively managed cropland and surface waters. Though these lands may help in attenuating peak discharge during major rainfall events, their major role would be in reducing the loads of nutrients and sediment to surface waters in normal years. In dry years or after flood storage benefits have been achieved, the land can be used for grazing or other uses consistent with their conservation plan.

Targeting the Wetland Reserve Program or the Conservation Reserve Program to lands that provide tangible economic benefits to local communities serves to offset, if not outweigh, the federal cost of the program. In watersheds with already high concentrations of the 395,000 ha (975,000 ac) of restored wetlands under the Wetland Reserve Program, protected under the Conservation Reserve Program, or in large sites over 405 ha (1000 ac), can be expected to have consequential impacts that will require confirmation in a future study. In addition, state and federal funds—over $40 million of federal funds just in the past two years—expended for the purchase of floodplain easements to restore natural floodplain functions, should be expected to affect the frequency of flooding events over time.

All of the watersheds studied have a high percentage of hydric soils on cropland. Though we cannot report the exact percentage because hydric soil information is generally not available on watersheds smaller than eight digit hydrologic units (only in the cases of Iowa River and Raccoon River watersheds is there close coincidence with the boundaries of the respective eight digit hydrologic units). Table 6 data suggest that from 16% for the smaller watersheds soils to almost 50% of the larger watershed soils are hydric and may have once been wetlands. For example, the Crow Creek watershed is part of the larger watershed designated as hydrologic unit 7080101 and 16% of this eight digit hydrologic unit constitutes agricultural land on hydric soils, amounting to roughly 26,649 ha (65,823 ac). Only 5,771.25 ha (14,255 ac) of palustrine wetlands (temporary wetlands typically found in upper basin landscapes) remain, while 78% of the watershed has agricultural cover. The water storage and denitrification functions of many of these hectares of hydric soils that formerly constituted wetlands could be restored if the hydrologic conditions were reestablished.

In some counties, existing CRP land could be retargeted to provide water storage in addition to wildlife, soil erosion, and water quality benefits. No new land would need to be retired. In the counties that encompassed Perry Creek, there were (in 1997) 2,385 ha (5,890 ac) devoted to CRP (Table 4). Yet only 810 ha (2000 ac) strategically targeted upstream in the Perry Creek watershed could provide significant protection against 10 year frequency runoff, assuming that three times the amount of land is necessary to retain the desired volume of runoff at the given depth.

Targeting CRP lands for flood storage benefits is already occurring in the Devils Lake Basin in North Dakota. Local, state, and federal agencies are collaborating in efforts to prevent the further rise of Spirit Lake, a lacustrine wetland in a closed watershed with no natural drainage in normal rainfall years, in order to avoid further flooding to the adjacent city of Devils Lake. The Texas Agricultural Experiment Station at Blackland Research Center estimates that the continuous forage cover generally required of CRP land has resulted in 36% less runoff than from cropland under small grain rotations typical for the area (Paul Dyke 1997).

Reducing the risk of highly costly, infrequent flood damage would involve contracting with owners of land that contained depressional areas or land that can, with minor modifications, retain runoff. Contracts would require that landowners temporarily plug drainage ditches for the duration of extreme flood risk.

Contracts may in fact differ by location to also allow for the retention of spring runoff that frequently carries nutrients that would otherwise be discharged to surface water bodies. In exchange for retaining water on their lands, producers are compensated for their opportunity cost of not growing an agricultural crop or producing a crop of lower monetary value. Communities that follow a policy of restricting development in areas subject to greater than one in 50 frequency flood events could set a goal of providing sufficient upper basin storage through contracts to prevent runoff events that exceed the 50 year threshold.

Table 6. Watershed characteristics.

Gaging station/ hydrologic unit	Hydric soils on cropland (% of watershed)*	Hectares with ag. cover on hydric soils* (palustrine)*	Wetlands hectares	Percent area having ag. cover*
Crow Creek part of 7080101	16	26,649	5,771.25	78
Iowa River all of 07080207 & part of 07080208	42/14.4	165,564/61,884	4909.4/18,329.5	95/95
Clear Creek part of 07080209	21	69,903	9,744.7	95.6
S. Skunk River part of 07080105	31	127,737	285.5	94.8
Squaw Creek part of 07080105	31	127,737	285.5	94.8
Beaver Creek part of 07100004	51.2	197,964	100.0	90.4
Raccoon River all of 07100007 & most of 07100006	18.6/50.1	46,332/270,661.5	3,835.8/7,952.6	94.7/94.4
Perry Creek most of 10230001	18.7	69,984	4,299.1	93

* Hectare figures relate to those in the eight-digit hydrologic unit (HUC). Where study water sheds represent only a portion of the HUC, figures are likely to exceed actual values.

The cost to landowners of the minor modifications may be offset in large measure by technical and financial assistance available through existing federal cost share and technical assistance programs, such as the Environmental Quality Incentive Program (USDA 1999b). The potential water quality benefits would justify the use of the funds for this purpose. The modifications, such as the control structures in controlled drainage, could be implemented as part of a farmer's regular maintenance program for tile drains. An additional offset for the cost of the structures and practices would be the economic benefit that accrues in normal years, when there are no extreme weather events and hence need to store water above ground that could adversely affect crop production. Studies by the USDA NRCS suggest that a system of water table management, utilizing the same structures for upland aboveground water storage, can result in a positive net return on the capital investment (Zucker 1998).

Owners of land containing depressions or poorly drained soils, such as hydric soils, may already be receiving federal assistance in the form of federally subsidized crop insurance or agricultural disaster assistance. These lands could be covered by a contract that stipulates that the farmers would be compensated not just a portion of their costs associated with producing a crop, but also a bonus that corresponds to the profit that they otherwise would have received had a crop been harvested. The contract would require, however, that drainage ditches and other water conveyances be plugged during the duration of flood events as a prerequisite for the bonus. These landowners would be paid for "harvesting" water for the years in which extreme weather events occur.

Storing runoff in depressional areas or areas that can be made to retain large amounts of water might actually reduce the total cost of crop insurance and disaster assistance, and thereby pay for the cost of the water storage bonus by decreasing the total land affected by flood runoff. Alternatively, the bonus may come in the form of higher federal subsidy of the premium for crop insurance.

Finally, communities may prefer a program of prevention that serves, in effect, as an insurance policy to having to expend considerable funds whenever there is a significant likelihood of flooding and consequent damages. By paying contractees an annual fee that is commensurate to the expected benefit, risk managers can reduce flood risk at a reasonable expense while providing an incentive to agricultural landowners to manage the landscape in such a way as to provide significant ongoing environmental benefits.

Conclusion

The results of this study suggest that a program of contracting with owners of upper basin agricultural land for temporary storage of runoff from extreme precipitation events can provide flood protection and improved water quality at a reasonable cost. The contracts could stipulate that farmers would be compensated for any or, alternatively, a specific percentage of the loss of expected income, perhaps on a five year or longer period.

The total cost is likely to be considerably below the expected outlays for flood damage related expenses. And unlike a program of wetland restoration alone where, under saturated soil conditions and low storage capacity, wetlands contribute minimally towards reducing peak floodwater discharge, temporary upper basin storage can renew storage capacity in anticipation of imminent extreme precipitation events. After the threat of flooding has passed, the stored runoff can be discharged to surface waters to create new storage capacity. A combined program of temporary storage on agricultural land and strategic restoration of wetlands can help at least partially restore the ecological integrity of watersheds.

A policy of encouraging upper basin storage would have secondary benefits, which may not be easily monetizable. These include retaining nutrient enriched spring runoff for a sufficient amount of time to cause denitrification and reduced nitrate loading to surface water bodies.

The value of this measure is clear in consideration of the need to reduce total nutrient load to the Gulf of Mexico to ameliorate its hypoxia problem. Another is providing wildlife habitat at critical spring and early summer flyover and nesting periods. Retaining water on the land for longer periods in the late winter and early summer serves to recharge ground water, raise surface water flows in summer months, and reduce the risk of droughts. The need for greater flood and drought mitigation measures is likely to become greater if the current predictions of global warming and greater frequency of extreme weather events are realized (Watson 1996).

This analysis does not provide sufficient information to indicate definitively the amount of land for storing runoff that would have prevented the actual floods that occurred in the watersheds indicated. Additional information on time of travel is needed, as well as the level of protection for the frequency of flood events that a community could withstand without material damage. However, it does suggest that there are sufficient hectares of upper basin depressional storage capacity to mitigate, if not prevent, flooding events, and that storing water through temporary restoration of wetland functions could serve as a cost effective alternative means towards flood mitigation.

Though there has been no examination of the costs and difficulty of administering the program or those of design and engineering, this problem is not likely to be insurmountable if the program were to be assumed under the aegis of the U.S.D.A.'s Natural Resource Conservation Service N.R.C.S. The NRCS, whose mission is to provide assistance to agricultural producers to achieve a variety of conservation objectives, has both the expertise and the technical assistance material for the relatively simple structures and practices that would be necessary to implement a program of temporary upland water storage. In fact, all of the practices are either covered in its National Engineering Handbook (USDA 1999) or, in the case of restricted flow culverts under roads that intersect agricultural lands, allow for straightforward design for the conditions of the land and water storage needs.

Hydraulics for reducing flooding through storing excess water in upland areas was not studied. Nor were intangible benefits of the temporary restoration of wetland functions (e.g., terrestrial wildlife or carbon sequestration to mitigate greenhouse gas emissions) examined. A followup study is necessary to investigate the specific practicality of upper basin storage in the respective watersheds, and to determine the extent to which flood water retention on specific upper basin lands could have mitigated flooding in previous years.

Finally, the problem of coordination among landowners for temporary water storage was not explored. If a storage or depressional area is transected by two or more property boundaries, all owners of the lands must agree on participation in the program. The need for consensus among landowners could conceivably lead to higher payments for water storage as each individual landowner seeks to negotiate a contract that provides higher payments than those made to neighbors. Alternatively, only potential storage area that lies within an individual producer's land is considered or a quasi governmental structure, such as a drainage or flood district would be established in the watershed that would set limits on contractual payments. Though an important problem, it deserves a separate and thorough examination before a program, such as the one proposed here, is attempted in a watershed.

ENDNOTES

[1] According to North Carolina State University Extension, controlled drainage can, under many circumstances, result in increased profit to farmers through reduced crop production costs. Therefore, estimating the net cost of structures for the purpose of upland storage is difficult.

[2] According to the March 1998 USDA Farm Service Agency Farm Program fact sheet on the Noninsured Crop Disaster Assistance Program, 1998 payments are made based on 60% of the average market price of the crop. After 1999, the pertinent figure is 55%. Similarly, the March 1997 fact sheet on the Catastrophic Crop Insurance Program states that the indemnity payment is 60% of the expected market price. Consideration of other agricultural disaster assistance programs, such as the Emergency Loan Assistance Program, may actually increase the ratio of assistance to crop market value to greater than 60%.

[3] According to meteorologists contacted at the National Weather Service and at state agencies, quantitative precipitation forecasting (QPF), though still in its infancy, can predict the quantity of precipitation in a watershed and the likelihood of flooding with a reasonable degree of accuracy and reliability—the latter quantified in a number of watersheds. The rule of thumb for predictions of the likelihood of rainfall events exceeding a given quantity in large watersheds is 50%. For smaller watersheds, it is 25%.

Disclaimer

The views and opinions expressed in this paper are those of the author and not necessarily of the U.S. Environmental Protection Agency. Nor do the results suggest policies of the federal government, unless expressly indicated.

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